



The REPAIR project: investigating the effects of sub-natural background radiation exposure within SNOLAB

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Research team

- Dr. Chris Thome
 - Medical physics
- Dr. Suji Tharmalingam
 - Molecular biology
- Dr. Doug Boreham
 - Radiation biology
- 2 PDF
- 3 graduate students
- 1 technologist



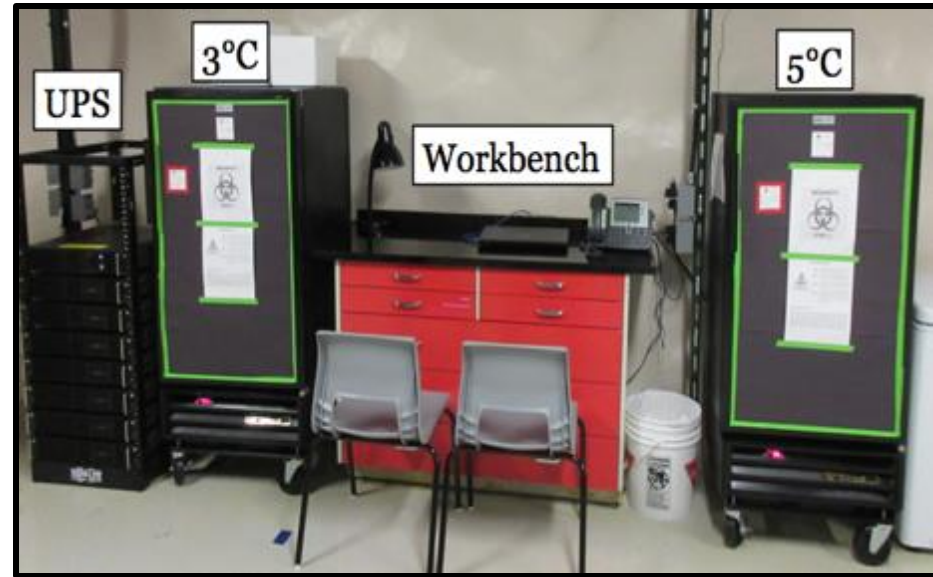
SNOLAB

- 2 km (6,800 ft) underground
 - 6 km water equivalent
 - 5×10^7 reduction in cosmic radiation
- Class 2,000 clean room
- HEPA filtration of $50 \text{ m}^3/\text{s}$
 - 10 full lab air exchanges per hour



SNOLAB Life Sciences Laboratory

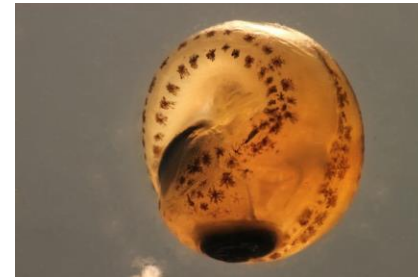
2015 – 2017



Pilot project: lake whitefish embryos

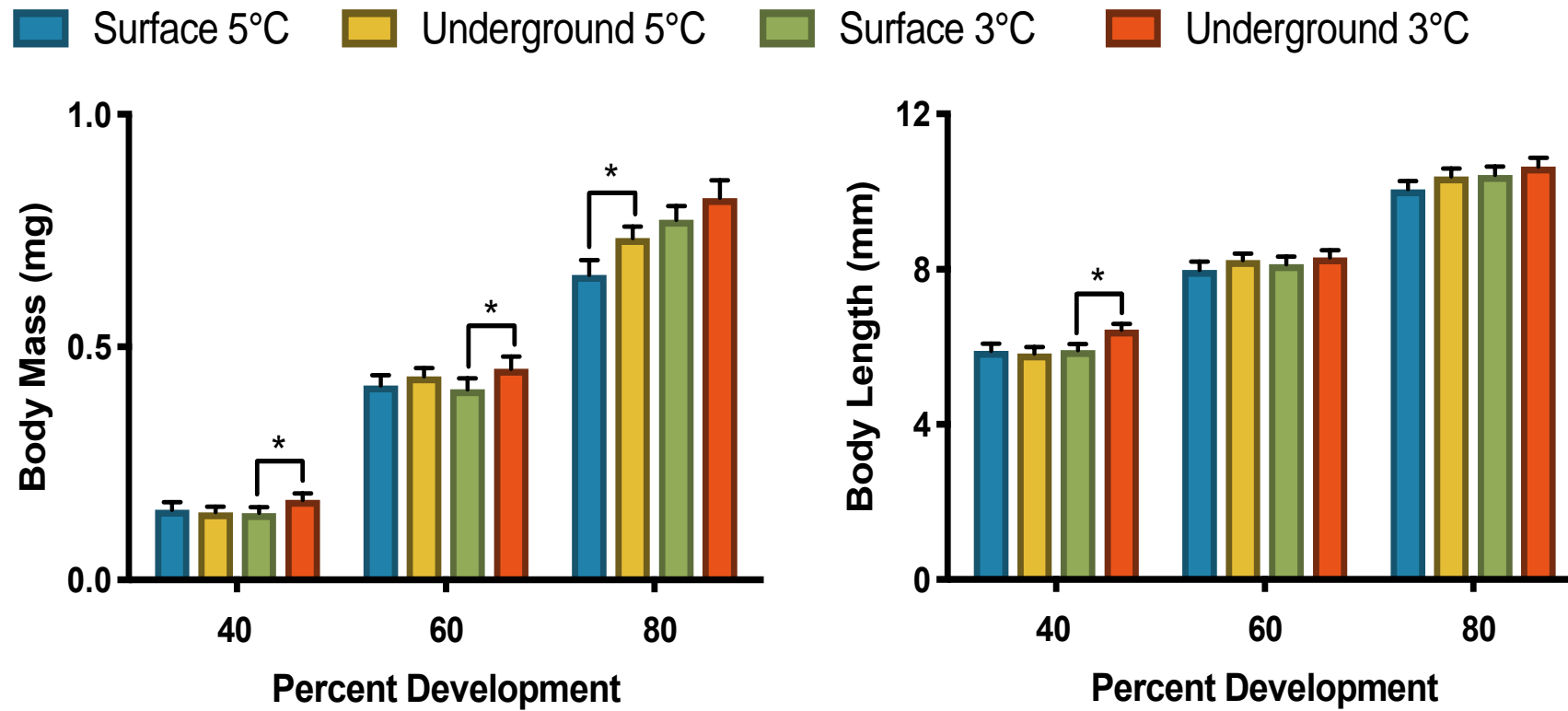


| | Temperature (°C ± SD) | Dishes | Embryos | Sampling timepoint (dpf*) | | |
|-----------------|--------------------------|--------|---------|---------------------------|-----|-----|
| | | | | 40% | 60% | 80% |
| Surface 5°C | 4.7 ± 0.2 | 39 | 1,950 | 38 | 58 | 79 |
| Underground 5°C | 4.6 ± 0.3 | 43 | 2,150 | 38 | 58 | 79 |
| Surface 3°C | 3.3 ± 0.4 | 38 | 1,900 | 50 | 73 | 101 |
| Underground 3°C | 3.4 ± 0.2 | 42 | 2,100 | 50 | 73 | 101 |



?

Pilot project: lake whitefish embryos

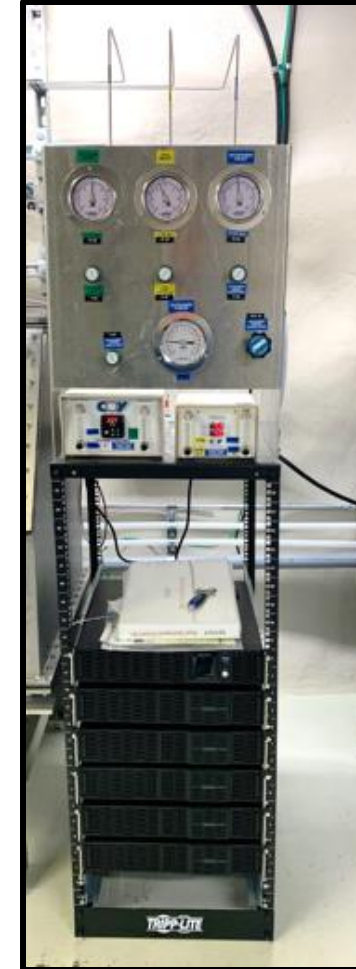


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Current



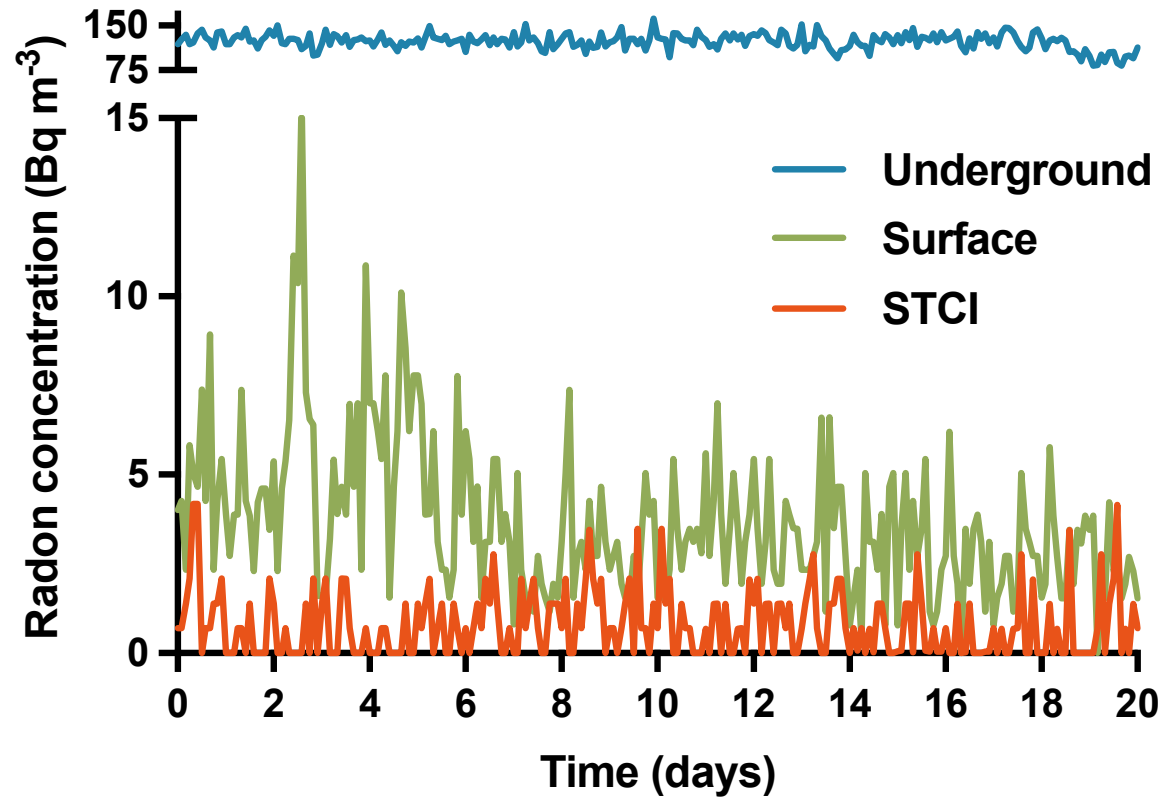
Specialized tissue culture incubator



Experimental environments

1. **Underground control:** standard tissue culture incubator in SNOLAB
2. **Surface control:** standard tissue culture incubator at NOSM
3. **Sub-background:** underground specialized tissue culture incubator (STCI)

Radon



Underground = 123 ± 16 Bq/m³

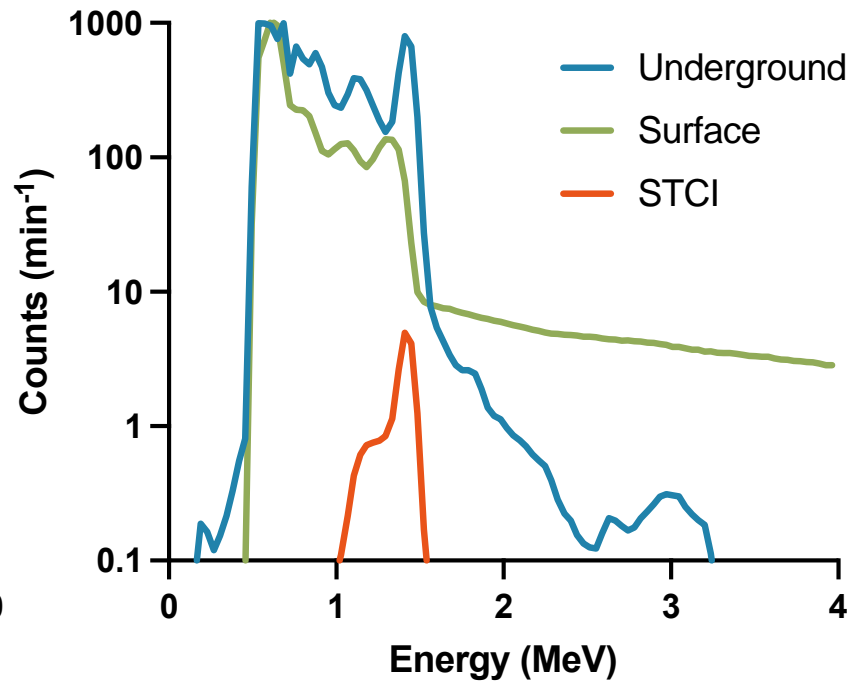
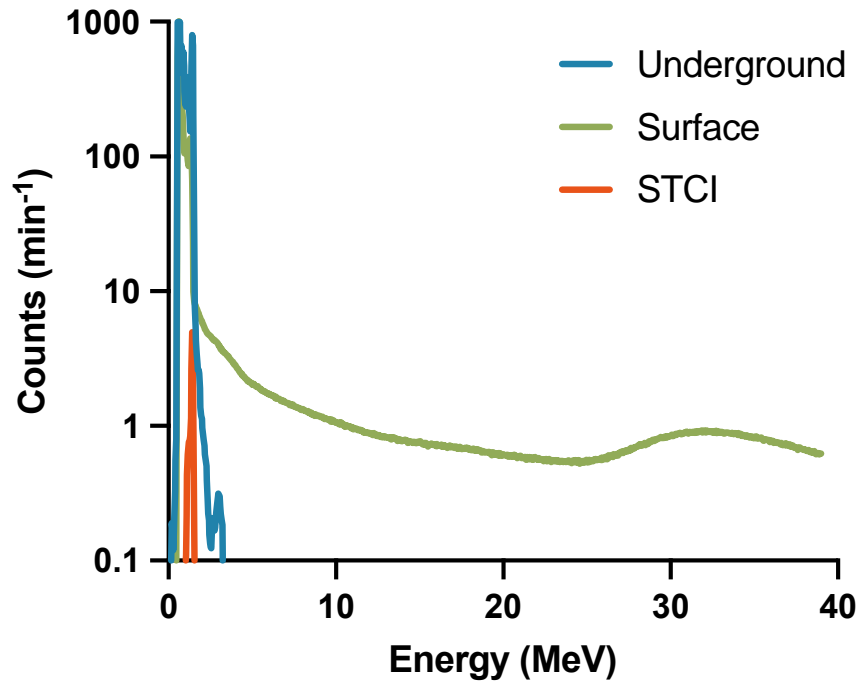
Surface = 3.7 ± 2.1 Bq/m³

STCI = 0.79 ± 0.93 Bq/m³



Aged gas cylinders
(CO₂, N₂, O₂) for a
minimum of one
month

Gamma



Internal



Potassium-40

8.0 ± 0.6 Bq/L
(216 ± 16 pCi/L)



Carbon-14

0.612 ± 0.004 Bq/L
(16.5 ± 0.1 pCi/L)

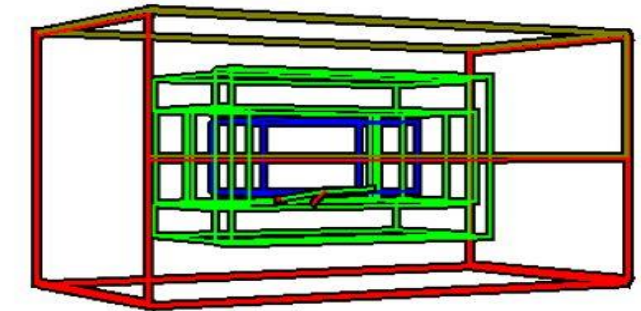
Absorbed dose rates

Dose rates were calculated using GEANT4 for:

- Gamma
- Neutron
- Muon

Dose rates were calculated using activity concentrations for:

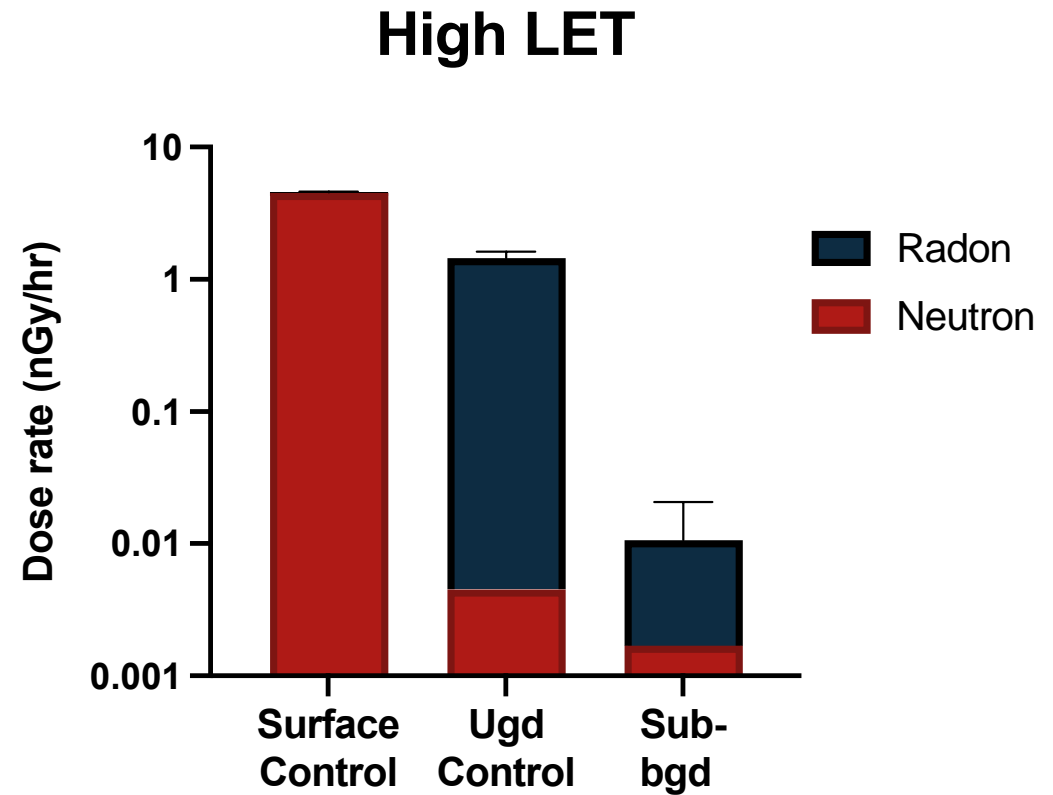
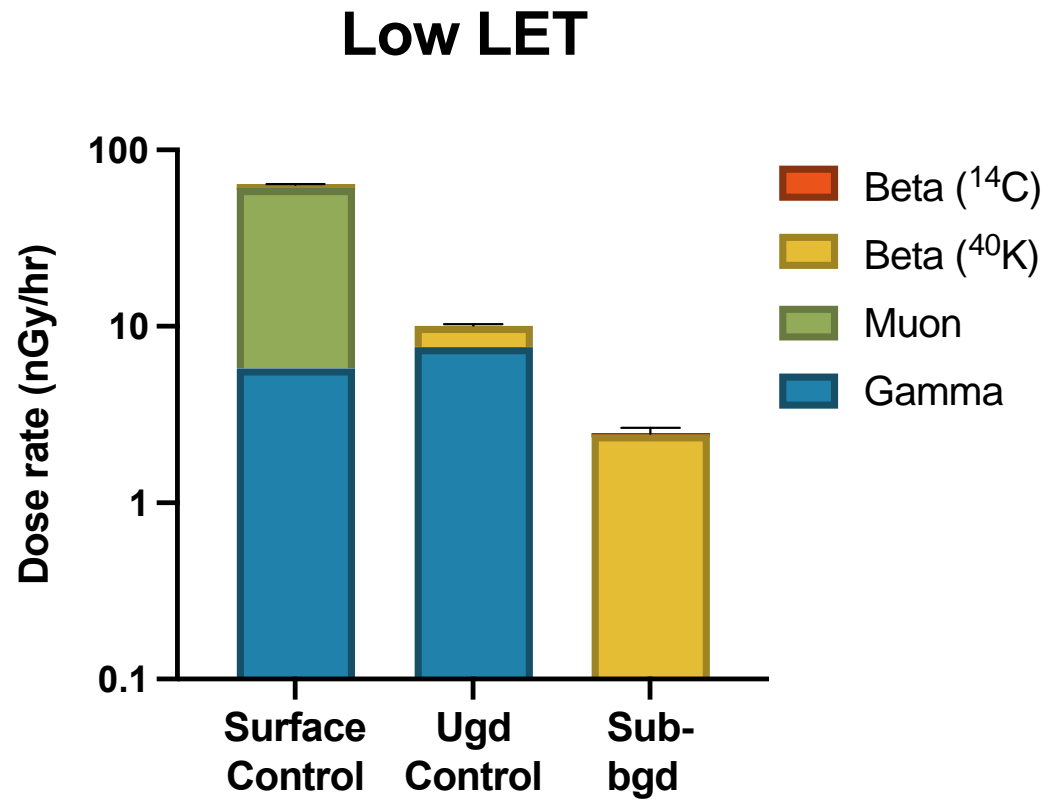
- Radon
- ^{40}K
- ^{14}C



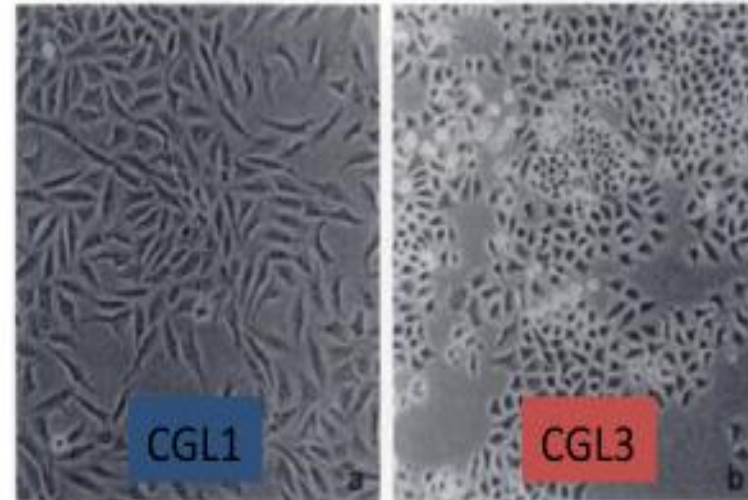
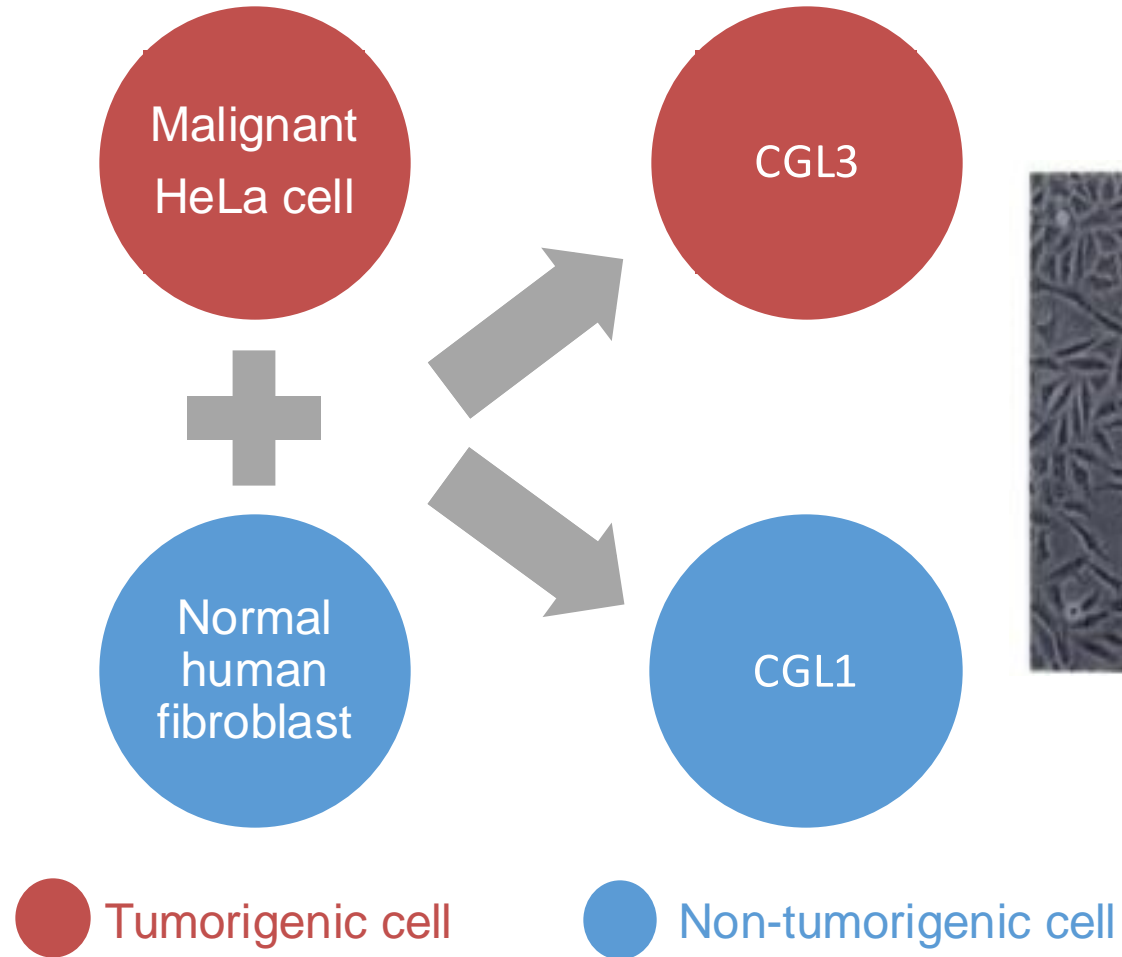
Absorbed dose rates

| Particle type | Surface control (nGy hr ⁻¹) | Underground control (nGy hr ⁻¹) | Sub-background (nGy hr ⁻¹) |
|-------------------|---|---|--|
| Gamma | 5.78 ± 0.03 | 7.67 ± 0.01 | 0.0427 ± 0.0013 |
| Neutron | 4.52 ± 0.04 | 0.0045 ± 0.0002 | 0.00169 ± 0.00002 |
| Muon | 55.27 ± 0.40 | Negligible | Negligible |
| ²²² Rn | 0.044 ± 0.014 | 1.45 ± 0.17 | 0.009 ± 0.011 |
| ⁴⁰ K | 2.41 ± 0.19 | 2.41 ± 0.19 | 2.41 ± 0.19 |
| ¹⁴ C | 0.0175 ± 0.0001 | 0.0175 ± 0.0001 | 0.0175 ± 0.0001 |
| Total | 68.04 ± 0.67 | 11.55 ± 0.37 | 2.48 ± 0.20 |

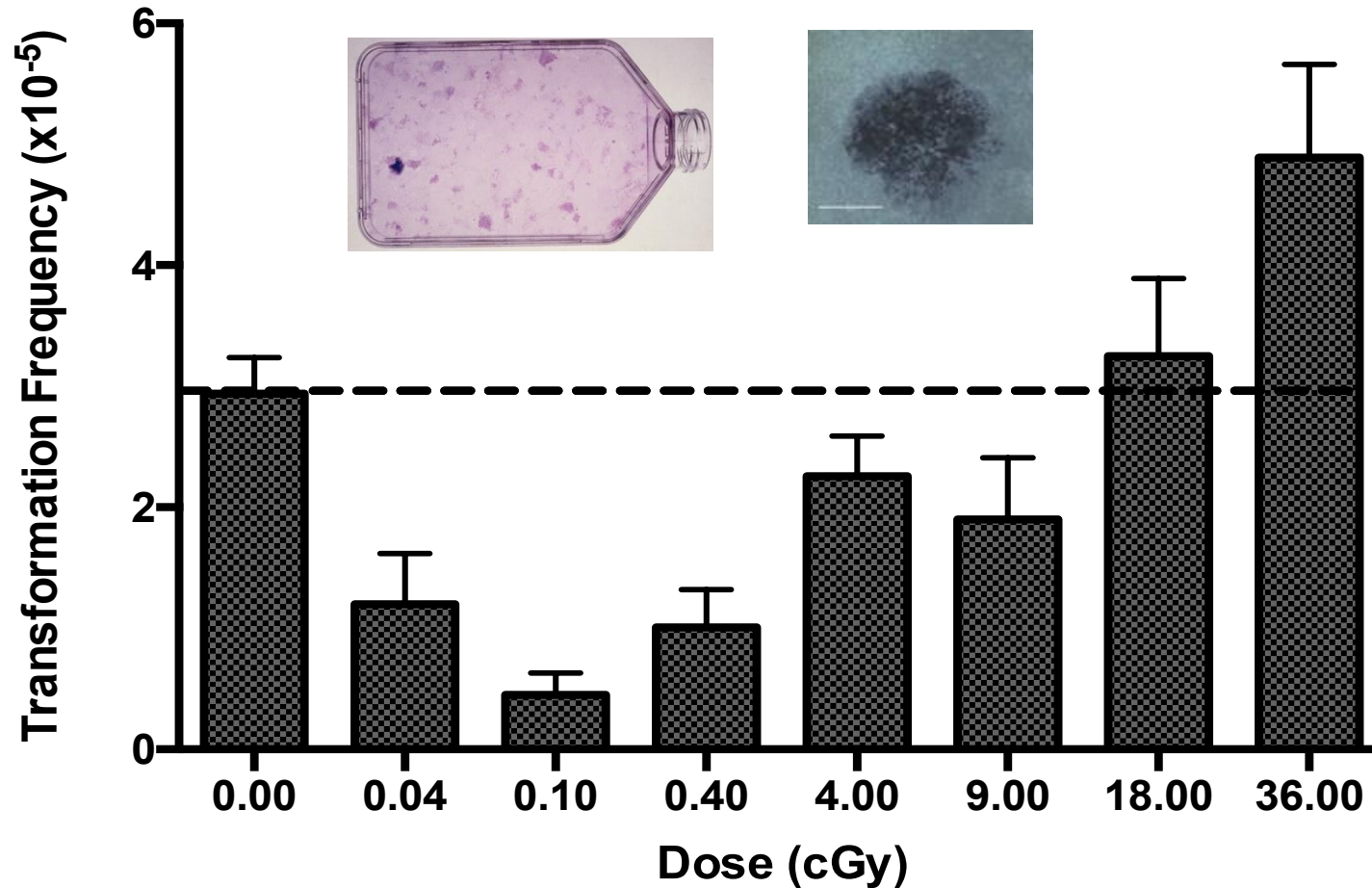
Absorbed dose rates



CGL1 cell line

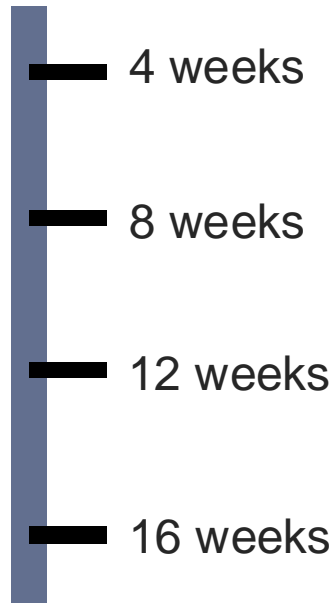


CGL1 cell line



Redpath et al. 2023 *Int J Radiat Biol*

Sub-background experiments



Sub-NBR
adapted cells



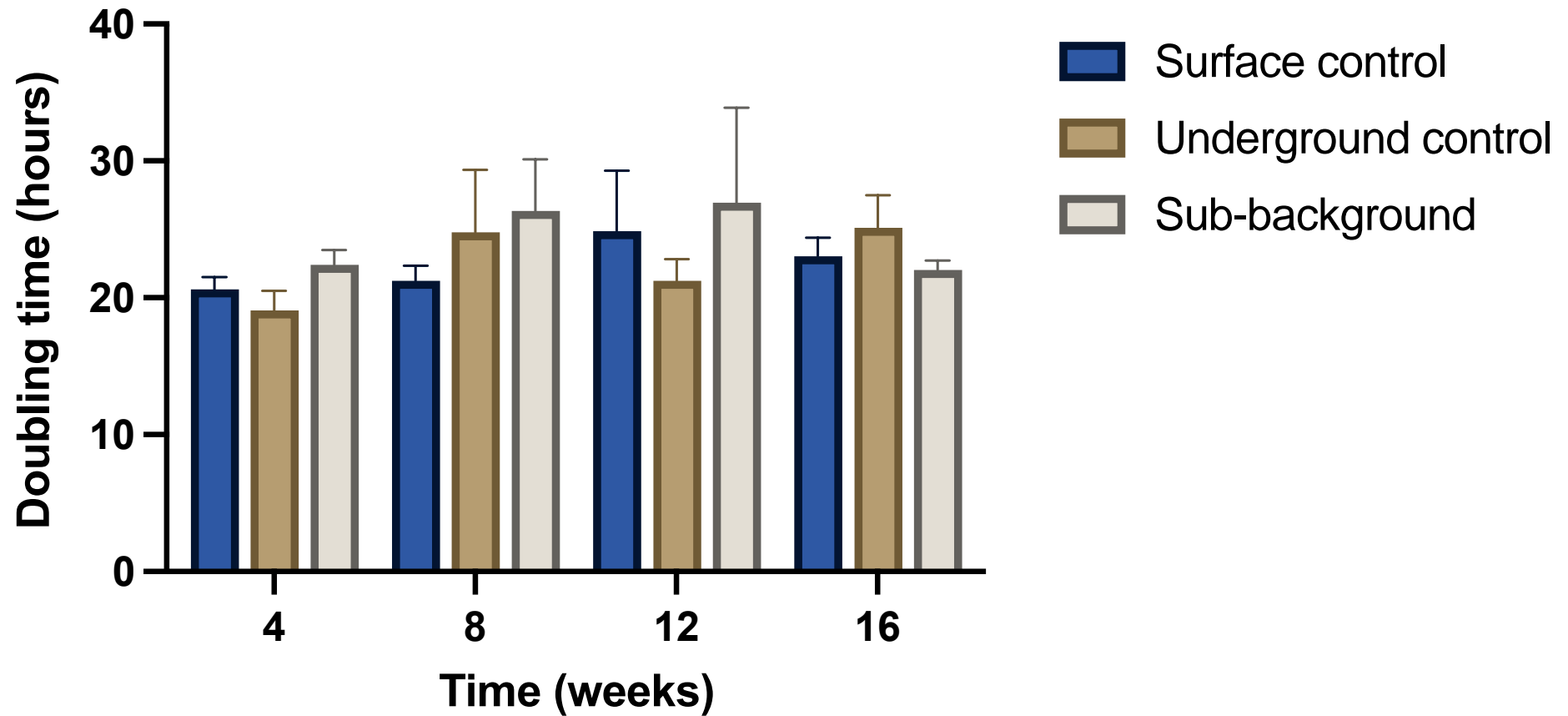
- 1. Baseline response**
- 2. Radiation challenge**



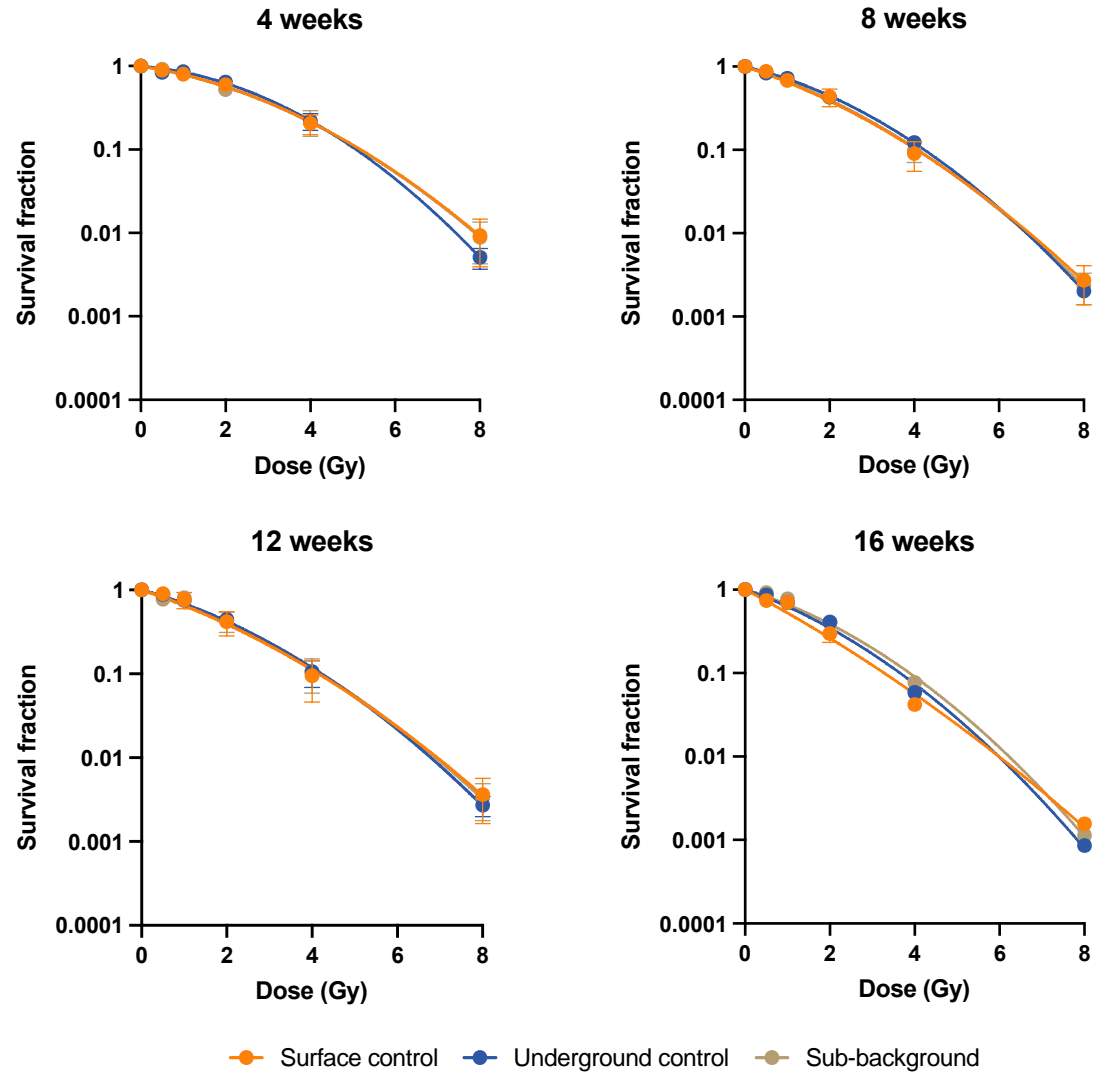
- Growth
- Survival
- DNA damage
- ALP activity



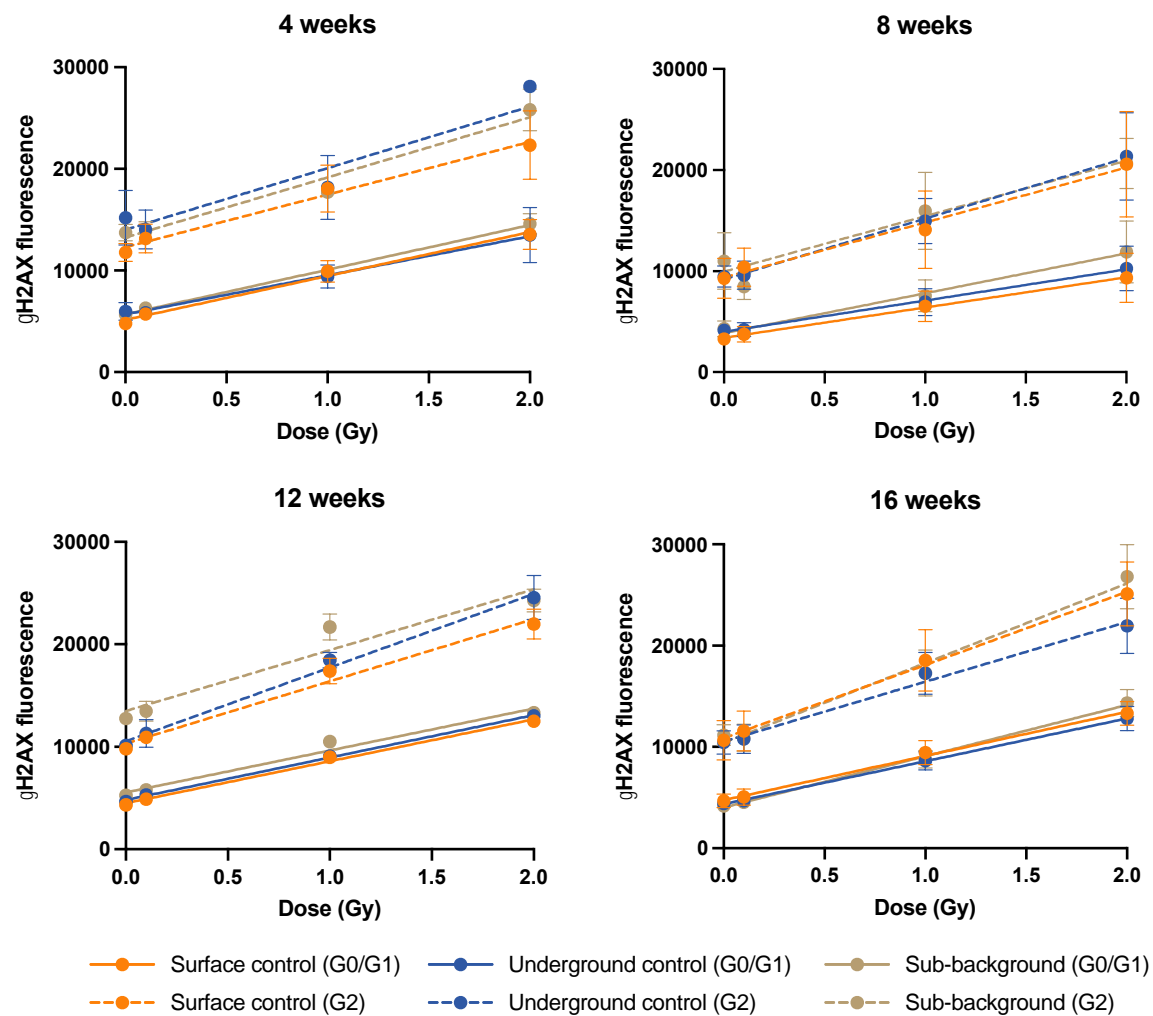
Growth



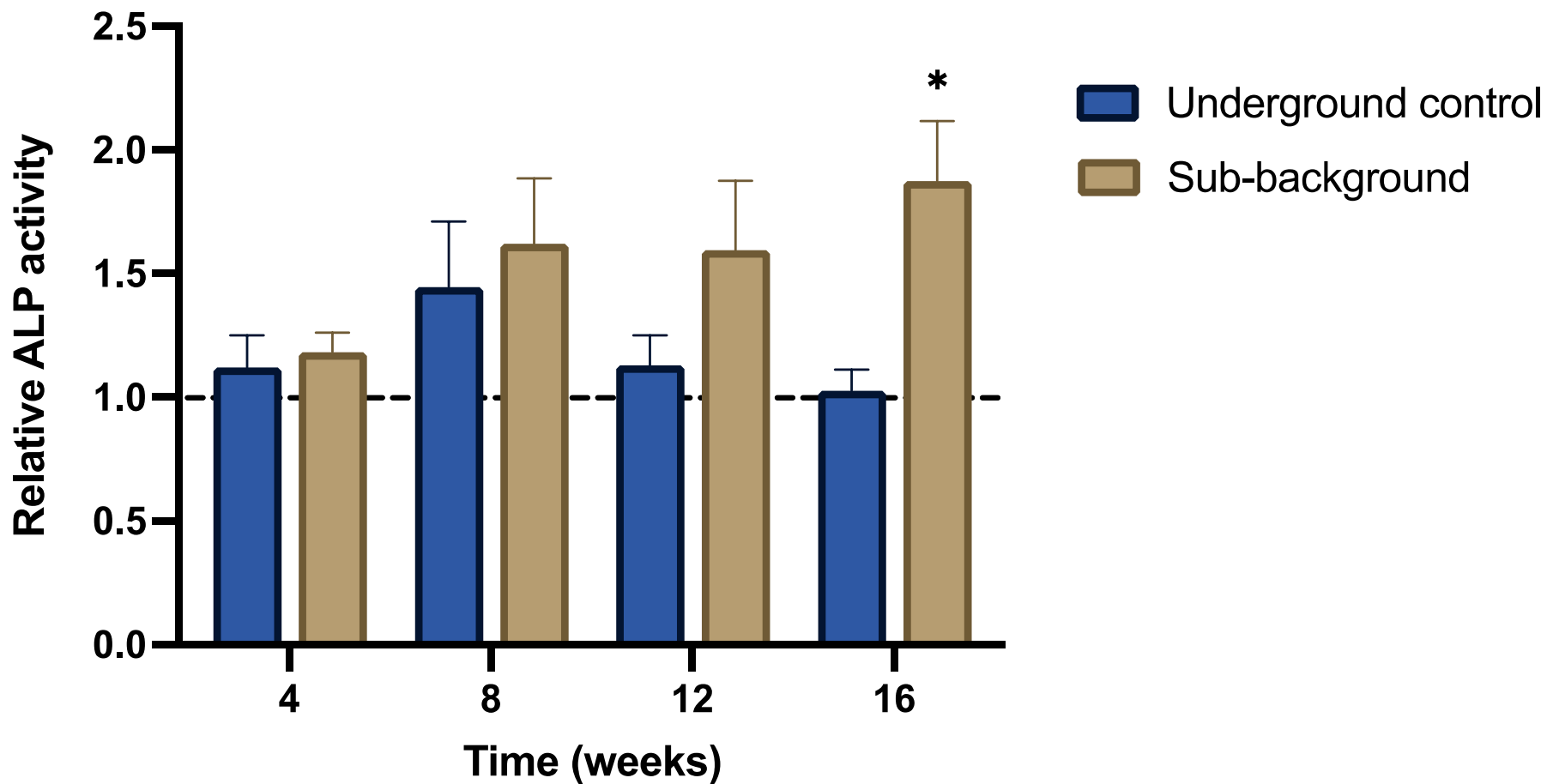
Survival



DNA damage

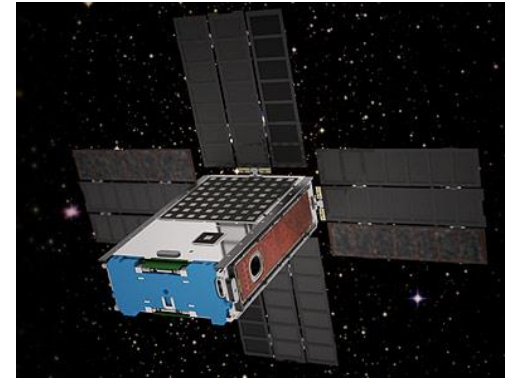


ALP activity

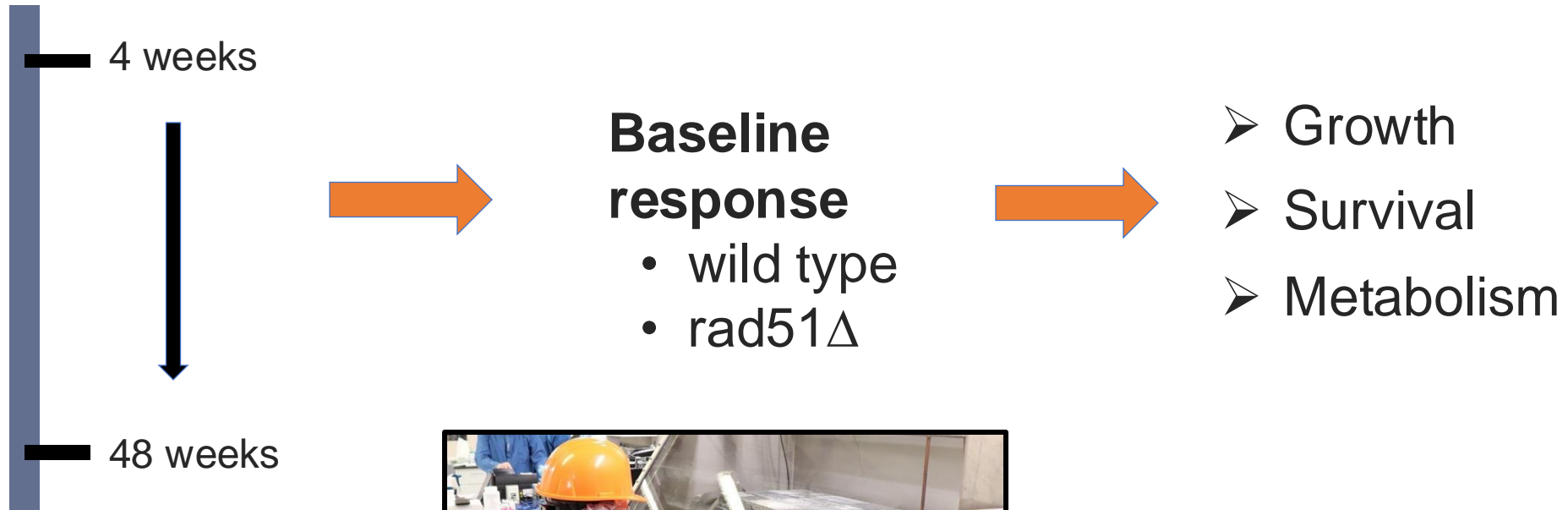


Saccharomyces cerevisiae

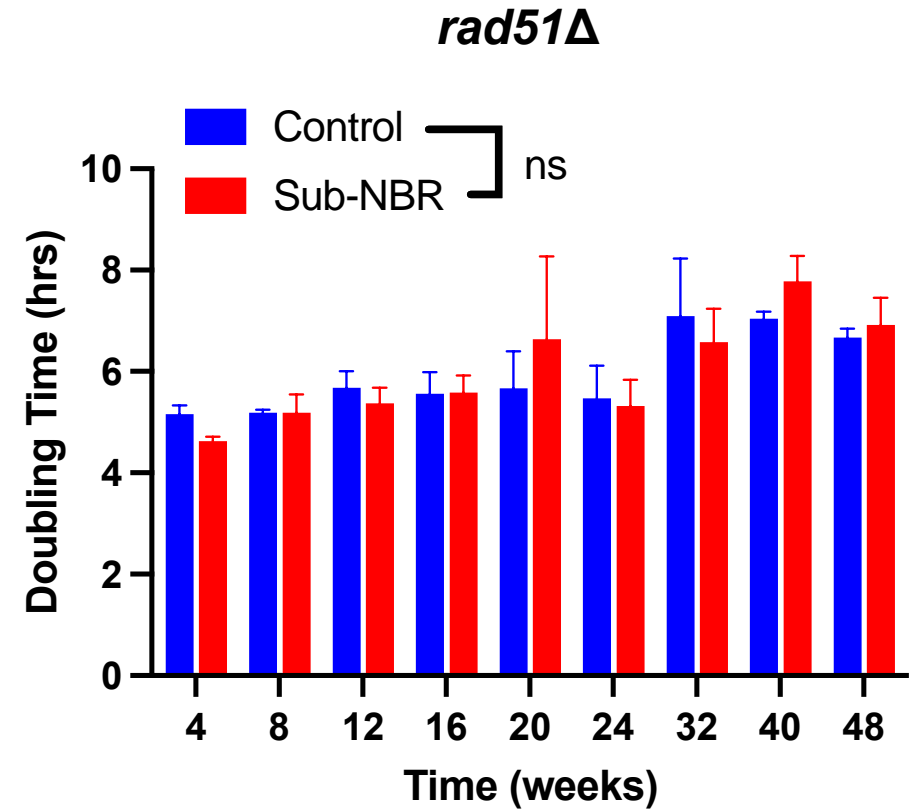
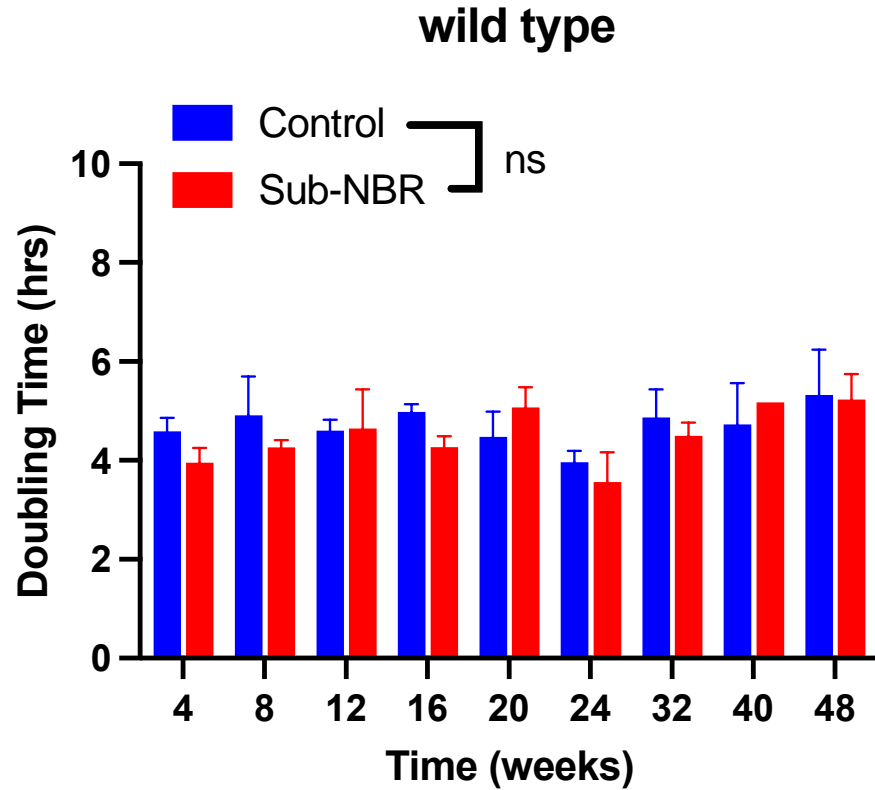
- Can survive in a state of anhydrobiosis
 - No food, water, oxygen
- Genomic damage still accumulates while desiccated
- Measure biological effects upon rehydration
- Availability of genetic mutant strains



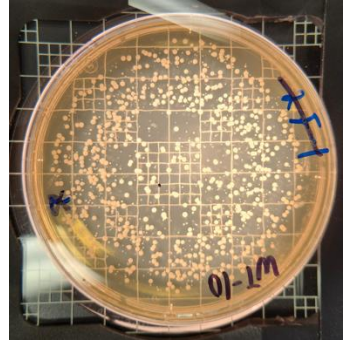
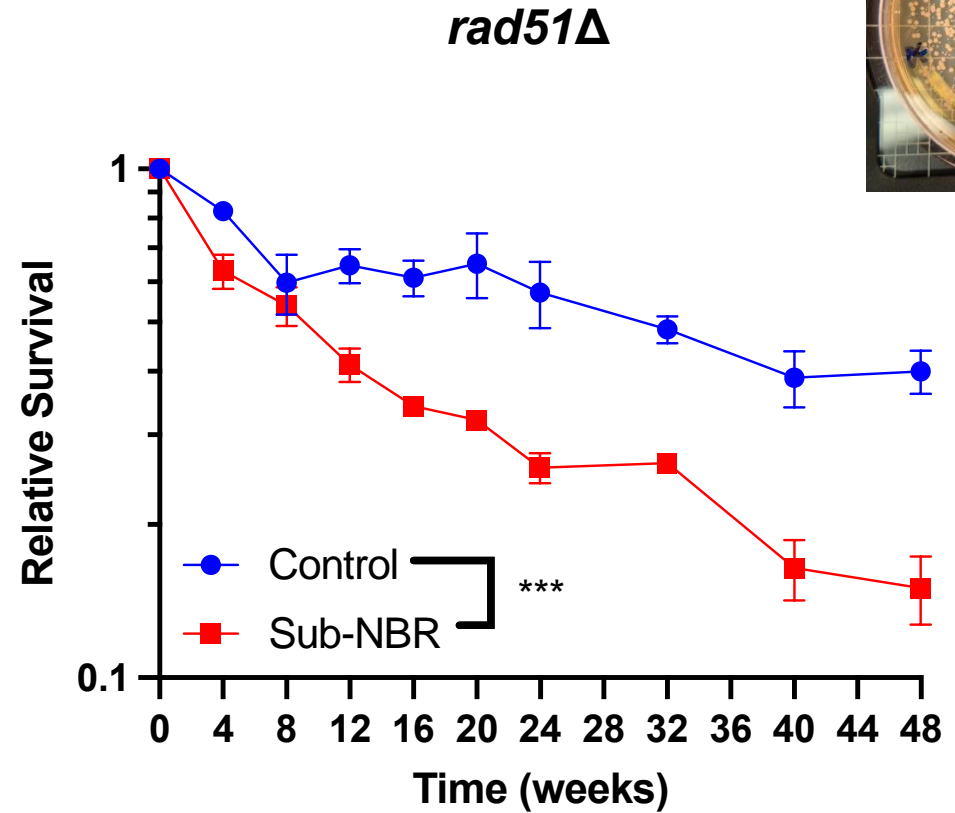
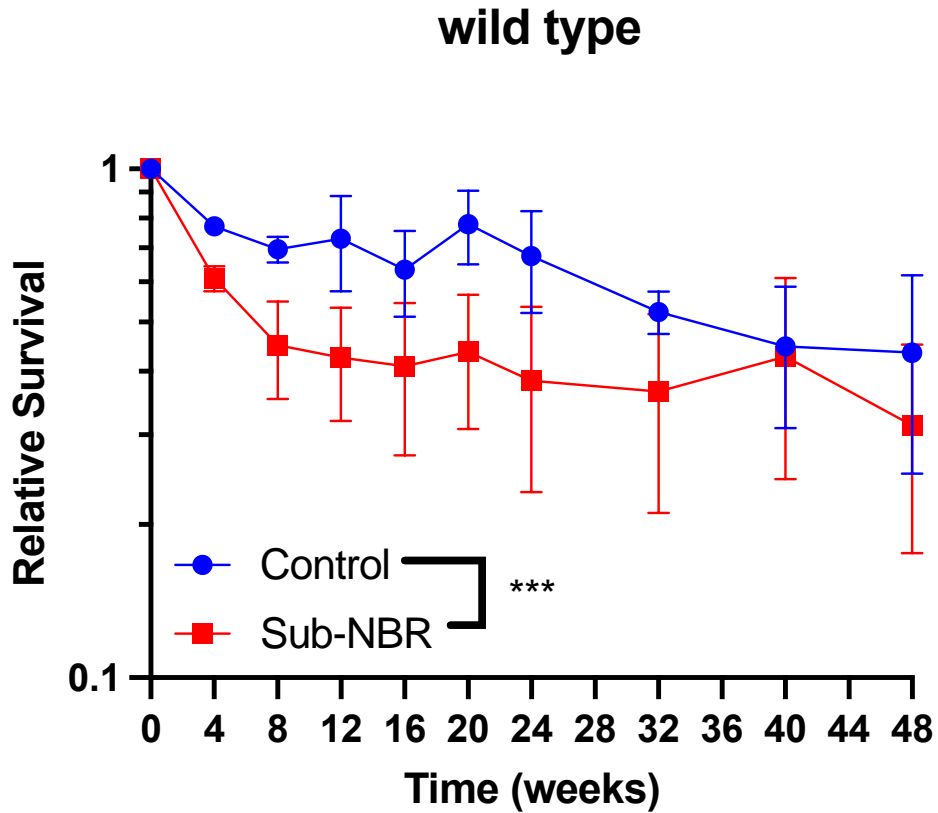
Sub-background experiments



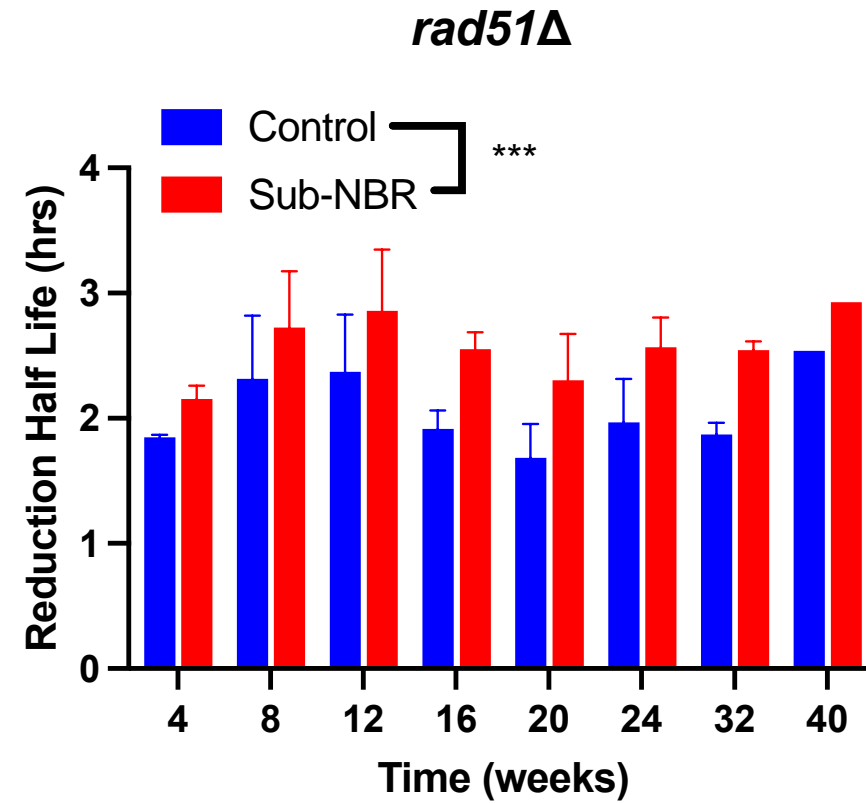
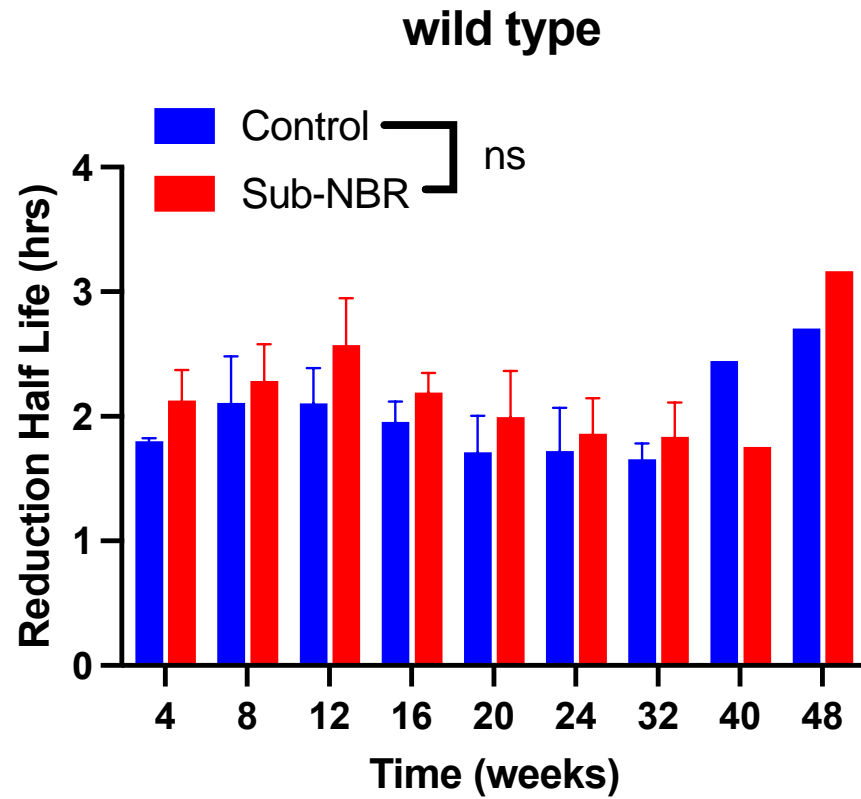
Growth



Survival

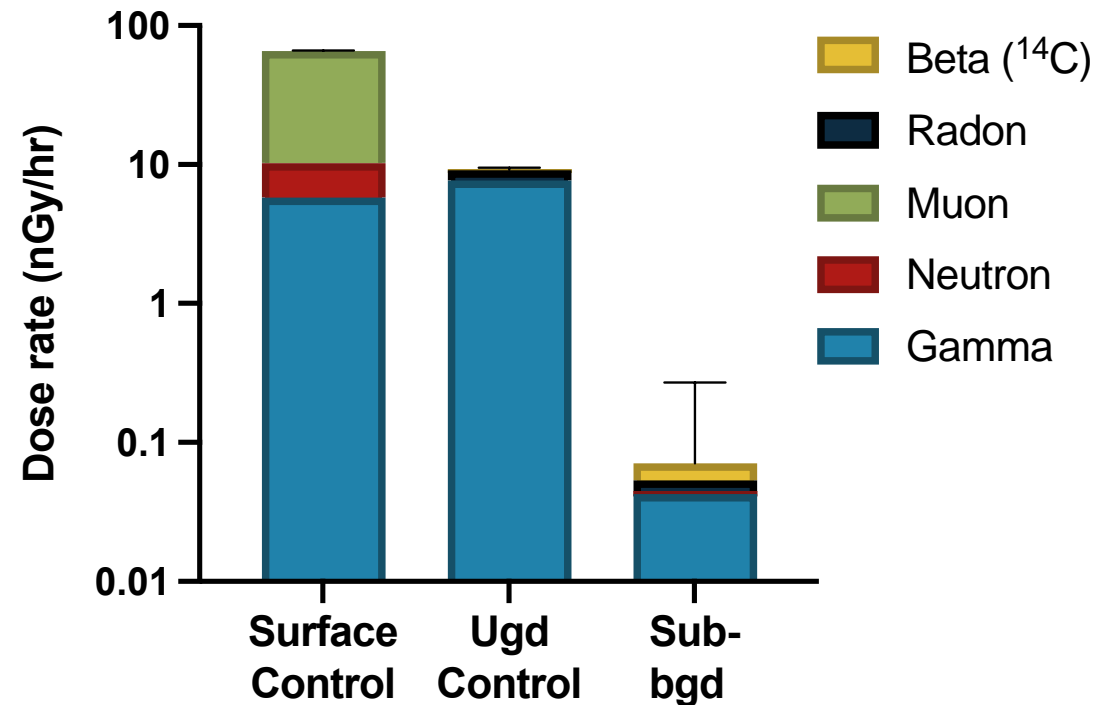


Metabolism



Next steps

- Internal ^{40}K dose reduction
- Molecular mechanisms
 - Transcriptomics
 - Proteomics
- Model systems
 - C elegans
 - Organoids
 - Drosophila



Acknowledgements

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